DISEASES OF COMMERCIALLY IMPORTANT CONIFERS IN THE PACIFIC NORTHWEST

IMPERIAL BUREAU OF MYCOLOGY
30 MAR. 1927

Compiled

by

J. S. Boyce

Pathologist

Office of Investigations in Forest Pathology

Bureau of Plant Industry

Portland, Oregon

Re-issued September 17, 1926

(Originally issued February 26, 1923, as U. S. Forest Service, Study Course 1923, District 6, Course V, Enemies of the Forest, Part I - Disease.)

Digitized by the Internet Archive
in 2025

https://archive.org/details/diseasesofcommer0000jsbo

C O N T E N T S

	Page
Introduction	1
Structure of the tree	1
Normal functions of the tree	2
Disease, a disturbance of normal functions	3
Causes of disease	3
Examination of diseased trees	6
Symptoms of disease	7
Fungi	9
Mistletoe	11
Diseases of Douglas fir	12
Decay	12
Mistletoe	15
Needle blight	16
Canker	16
Diseases of western hemlock	17
Decay	17
Mistletoe	18
Diseases of Sitka spruce	18
Decay	18
Needle cast	19
Needle rust	19
Diseases of balsam firs	19
Decay	19
Mistletoe	20
Needle cast	21
Needle rust	21
Yellow witches' broom	21
Diseases of western red cedar	21
Decay	21
Leaf blight	22
Diseases of Port Orford cedar	22
Diseases of incense cedar	22
Decay	22
Mistletoe	25
Rust	25

Diseases of western larch 26
Decay 26
Mistletoe 26
Needle cast 27

Diseases of western yellow pine 27
Decay 27
Mistletoe 28
Needle cast 28
Stunted needles and witches' broom 28
Pine gall rust 29

Diseases of sugar pine 29
Decay 29
Mistletoe 29
Blue witches' broom 29
White pine blist r rust 29

Diseases of lodgepole pine 30
Decay 30
Mistletoe 30
Pine gall rust 30

Diseases of western white pine 30
Decay 30
Mistletoe 31
White pine blister rust 31

Control of disease 33
Mistletoe 33
Fungus diseases 35

Conclusion 35

DISEASES OF COMMERCIALLY IMPORTANT CONIFERS IN THE PACIFIC NORTHWEST*

INTRODUCTION

Forest tree diseases are a grave menace. As a matter of fact the average forester does not fully realize the enormous damage resulting from this source. Chestnut blight (Endothia parasitica), a native of Asia, has already accounted for half the stand of native chestnut (Castanea dentata) in the eastern United States and will probably have killed all trees east of the Mississippi by 1940. Before this disease was introduced the total value of chestnut was estimated at from 300 to 400 million dollars. The total value of chestnut products, not counting the nuts, reached almost $20,000,000 in 1911. White pine blister rust (Cronartium ribicola) introduced into the eastern United States from Germany and France, is now present in British Columbia and Washington, thus threatening the existence of western white and sugar pine. In addition to these imported parasites, there are innumerable native diseases, which, while they do not eliminate any commercial species completely, nevertheless take an enormous annual toll from our forests by actually killing outright some merchantable timber or reproduction, by reducing the annual increment of trees of all sizes, or by decaying the heartwood of merchantable trees.

The object of studying forest tree diseases is to learn how to prevent and control them. Consequently it is necessary to know the more common diseases, how they appear, the injury they cause, and the consequences of the injury. Stated in the simplest terms, disease is a disturbance of the normal functions of a tree, and to understand the nature of disease it is essential to understand these functions and the structure of trees.

STRUCTURE OF THE TREE

Trees grow in length in the youngest (end) part of the twigs and at the very ends of the roots; they grow in thickness in the so-called cambium, a very thin layer of cells between the bark and the wood of roots, stem, and branches. The cells of the twig ends, of the root tips and of the cambium are capable of division and certain young cells produced by this division, if properly nourished, grow to normal size, divide in turn, and so on. The growth in thickness (diameter) by the cambium takes place only in spring and early summer, and results in the production of a thin layer of wood all over the tree. In cross section this layer appears in the shape of the so-called annual ring, corresponding to one year's growth in diameter. The springwood of the annual ring is light and soft; the summerwood appears as a narrower, darker line and is harder than the other.

---

*The information in this paper has been compiled from publications of E. P. Meinecke and J. R. Weir and from publications and unpublished manuscripts of the writer. Both Meinecke and Weir, particularly the first named, have been quoted extensively, but it has not been feasible to indicate or credit each quotation.

After a number of years the cells of the oldest annual rings of wood die and after undergoing chemical changes form what is called the heartwood. The living wood outside of the heartwood is called sapwood.

Only the inner portion of the bark adjoining the sapwood and separated from it by the very thin cambium is living; the outer portion consists of an impermeable skin or layer of cork or cork scales. The thicker these layers of cork scales the better protection they offer the living tissues from fungi and mistletoes, but not from insects.

NORMAL FUNCTIONS OF THE TREE

All plants with green leaves or needles contain a green pigment which enables them to live on the very simplest food. They take up water and mineral salts through the roots and carbon dioxide and oxygen through the leaves; with the help of the green pigment the plants produce under the influence of sunlight from these chemically simple materials the bulk of the chemically very complex substances of which they are built up. This function can be carried on only in sunlight. Animals and fungi, on the contrary, live on chemically very complex food which they break up into simpler substances.

Large quantities of water containing comparatively little mineral salts are taken up by hairs on the very tips of the roots which have to be continually renewed. Older roots take no part in this pumping of water from the ground. Their role is to anchor the plant in the soil. The roots, if not too old, also breathe to a certain extent, that is, they take oxygen from the air in the soil.

The water with the mineral salts is pumped through the roots and then through the trunk in the sapwood upward to the leaves or needles. Enormous quantities of water are given off by the foliage in transpiration. The mineral salts accumulate and are utilized for various purposes.

The green leaves have three distinct functions - transpiration of water and its regulation, breathing (respiration), and assimilation of carbon dioxide.

Transpiration of water takes place through innumerable small openings in the leaves which regulate to a certain degree the quantity of water thus given off.

Every plant breathes (respires) exactly as every animal does; that is, oxygen is taken up and carbon dioxide, the product of respiration, is discarded. This process goes on day and night exactly as in the case of animals.

Carbon dioxide (a gas consisting of carbon and oxygen) from the atmosphere is assimilated by green leaves under the influence of sunlight. The carbon from the carbon dioxide, together with the water and mineral salts brought up from the roots, is used in the formation of

chemical substances of highly complex nature (starch and sugar); the oxygen from the same source is exhaled. In the leaves also takes place the assimilation of nitrogenous salts and formation of albumen.

Starch, sugar, and albumens furnish food for the growing cells of the cambium and the root tips, being transported from the leaves, where they are formed, downward through the living bark. The surplus above the amount consumed is stored.

All these functions must be perfectly balanced. The development of the root system, for instance, which supplies the water and mineral salts, is not independent of the development of the foliage. Both are correlated, and one must not overbalance the other.

DISEASE A DISTURBANCE OF NORMAL FUNCTIONS

All diseases, properly speaking, can be traced to some interference with the normal functions just described and the economic equilibrium established in a sound tree.

Leaf diseases, by killing a greater part of the foliage, destroy the very organs in which food for the growing tissues of the tree is prepared. The cambium does not receive proper nourishment and can not grow, while the hairs on the root tips, which must be renewed continually, are no longer developed for lack of food, with the result that when once the surplus of food in storage in the wood is also exhausted no more water is pumped up to the remaining leaves.

Diseases of the bark of branches and trunk intercept the flow of the food coming down in the bark from the leaves. The result is starvation of cambium and roots. This explains how damage is done by mistletoes, by bark-destroying fungi, and by bark beetles. The effect is the same as girdling the tree with an ax. The bark also stores reserve materials which are eliminated by the disease.

Diseases of the sapwood cut off the water supply which is pumped upward from the roots in the living sapwood to the upper parts of the tree, and the leaves suffer or die of drought. Any reserve materials stored in the sapwood are lost to the tree.

Diseases of the root system have the same disastrous effect on the water supply of the tree, and destroy the reserve materials stored in the roots.

Diseases of the flowers and seeds destroy the faculty of reproduction.

CAUSES OF DISEASE

Whenever a tree, growing under the same conditions as its thrifty neighbors, appears in any way unhealthy there is reason to assume some kind of attack by parasitic fungi, mistletoes, or insects. Yet there are

quite a number of other things which bring about diseases or death in trees, and before we decide finally that one of the three factors named is responsible, except of course where there can be no possible doubt, we should first make sure that there is not some other cause of the abnormal condition of the tree in question. Parasites are plants or animals which live off the living tissues of other plants or animals, not merely by mechanically destroying them, but by partly or totally penetrating the tissues of the so-called "host" - that is, the plant or animal they live on. Certain parasites are able to enter the youngest parts of trees, twigs, or leaves directly; the majority of fungi causing decay of the wood can get into the interior of the living tree only by way of a pin knot or wound. For this reason every wound caused by lightning, by fire, by man or by animals constitutes a menace of infection, unless it receives an aseptic dressing such as the coniferous trees to a certain extent give in covering the exposed surface with resin.

Smaller wounds in pines are, as a rule, soon covered over by pitch, which very effectively prevents the drying out of the exposed sapwood and the germination and growth of fungus spores. The less resinous conifers and our broadleaf trees lack this protection, and even the pines are unable to cover very large wounds completely. The sapwood dies, dries out, and checks. Spores (see "Fungi") of parasitic fungi enter the cracks, germinate, and infect the heartwood. Proper moisture and temperature are the necessary conditions for germination of the spores; but infection can only take place if the spores land where the mycelium (see "Fungi") resulting from germination finds the proper food for further development. The spore of the heartwood-inhabiting fungus, such as Polyporus amarus, causing the common dry-rot of incense cedar for instance, must be carried on to an incense cedar, since the fungus can not attack any other tree. If it lands on the bark it may germinate, but the resulting mycelium is unable to penetrate into the heartwood. Only when a spore is deposited on a broken off branch stub, which allows the mycelium to grow through it into the heartwood of the bole, or when a spore falls onto an open wound large and deep enough to offer an entrance into the heartwood either directly or through cracks, can infection take place. Thus certain diseases of the heartwood (rot or decay) can very frequently be traced directly to fire scars, lightning scars, spike tops, stubs of broken limbs and branches, and even to the crotches of forked trees, where the swaying of the two forks in the wind mechanically destroys the tissues. Moisture naturally gathers here, and spores find the most favorable conditions for germination.

Resin is not the only means of natural protection. All trees have the faculty, though in varying degrees, of healing over wounds and growing over pin knots and stubs. This is, of course, a very slow process and the tree is subject to infection until it is completed.

Purely mechanical destruction is not disease, but it may produce disease. Porcupines, for instance, will live off the tender bark of young pines (western yellow pine, lodgepole pine) when the snow is too deep for them to get any other food. As long as they destroy only small patches of living bark no material damage is done. Insignificant injury caused by mechanical destruction of small parts of vital organs is soon

overcome in a healthy tree; the remaining sound tissues simply take over the surplus work to be done - they work "overtime". But when not enough bark remains to perform the functions required of it, all parts of the tree above the point of attack soon show signs of suffering. The same holds true for insects. A tree scarcely suffers from the attack of isolated insects; but when they appear in great numbers and practically girdle the trunk the tree is seriously injured.

Mechanical destruction is brought about by man, by animals, by lightning, fire, storm, cloudbursts, heavy snowfall, etc. Carelessness in felling timber, removal of bark for roofing of cabins, unnecessary and extravagant blazing, tapping of yellow pines for resin are only a few examples of the destructive activity of man in the forest. Insects destroy the foliage, fruit, bark, or wood. Porcupines, deer, cattle, sheep, and other mammals partly live off the green bark, partly browse off the foliage. Rodents sometimes injure the roots, particularly of very young trees.

Lightning will not in every case kill the tree it strikes. As a rule, however, its effect is only realized when a heavy discharge strikes a tree and injures it very severely. But when, as in most cases, the electricity discharged over a forest is divided into a number of weaker currents, which strike as many dominant trees, each of which act as a conductor, the effect on the single tree becomes less apparent and is easily overlooked. Lightning is very often the cause of spike tops. Grooves and streaks on the bark and smaller wounds caused by lightning are very common.

The effects of fire are too well known to need description. It should be remembered, however, that often a tree may appear green and healthy for as long as two or three years after a fire, only to succumb at last to the injuries received. Decay in very many cases is directly traceable to old fire scars; in fact, fire as a cause of wounds is responsible for more cases of heartrot than all other factors taken together. The charred surface of exposed wood in the beginning affords protection to the wood underneath it, but soon the charcoal is partly worn off and the sapwood, which is no longer protected by the bark, dies and checks, thus offering an easy entrance to the germinating spores of wood-destroying fungi.

Heavy storms may injure a tree in various ways. Tops or limbs or the trunk are broken off. Sometimes part of the roots of a tree which is poorly anchored in the soil may be torn off and the tree completely uprooted and blown over. In falling such trees frequently injure their neighbors.

When a cloudburst displaces the ordinary bed of a mountain stream, any trees caught in the torrent, even if they withstand the pressure of the water, suffer more or less from the action of rolling boulders, which rub off the bark, and later from the changes brought about in their life conditions by the thick layer of debris left after the stream has receded.

Other causes of disease are smelter fumes and smoke, frosts, sunscald, drought, and excess of water in the soil. In the neighborhood of smelters and other large industrial plants which burn great quantities of coal, the forests particularly in the direction of the prevailing winds, are often very seriously injured by the poisonous gases escaping either from the ore or from the coal used.

Winter frost sometimes causes long internal cracks in older forest trees, often corresponding to rather conspicuous perpendicular ridges on the outside of the trunk. Late frosts are likely to kill young shoots. In long dry winters the foliage of coniferous trees is often stimulated on warmer days to transpiration of water, which the root system is not able to restore from the frost-bound soil. The needles then die and turn red. This is known as winter injury, red belt, or parch blight, depending on the species affected.

Sunscald is common on thin-barked trees, particularly after sudden exposure to strong sunlight by thinning, snowbreak, etc.

Heavy snowfall often causes serious damage by bending and breaking young trees or branches, or by favoring the development of certain fungi.

EXAMINATION OF DISEASED TREES

The nature of a disease can be determined only by keeping in mind all the possible factors which make for disease (see "Causes of disease"), and the way they affect the functions of the normal tree (see "Disease a disturbance of normal functions"). By taking into consideration all possibilities and by discarding everything that does not suit the particular case, we finally arrive at a comparatively small group from which by careful examination we will, as a rule, be able to choose the correct answer to our problem. It should be remembered, however, that a disease is not always encountered under its most typical aspect. A tree attacked by a fungus may show signs of suffering, but the fungus itself may not yet be sufficiently developed to form fruiting bodies (see "Fungi"). In other cases the fruiting bodies may be very small, very inconspicuous, or hidden on the roots or under the bark. The fruiting bodies of certain fungi even vary considerably with host and climate. Examination of diseased trees, therefore, can not be too careful.

No age is free from disease; but certain diseases are confined to definite ages. Some fungi, for instance, only attack young reproduction or branches and twigs in the same youthful stage of development. Others are confined to mature and overmature trees.

Few implements are required for the examination of diseased trees; a hatchet or an ax is sufficient for opening up the bark or outer layers of wood. A pick and shovel are needed when the seat of the disease seems to be in the root system. Whenever parts of the trunk, branches, or the root system are affected or killed it is important to find out the extent of the disease and, if possible, to follow any abnormal signs to their source. For the examination of the foliage an ordinary magnifying glass will do in most cases.

SYMPTOMS OF DISEASE

The foliage being the most sensitive visible organ, its general aspect is a valuable index of the health of a tree. When the foliage of a coniferous tree, for example, appears to be diseased, and no other cause, such as drought, girdling, smelter fumes, or recent fire, can be found, the needles should be held up to the light to see whether they are hollowed out by needle miners, the larvae or pupae of which may at certain times be found inside them. Partial or total destruction of the needles or leaves is due to browsing by mammals or to caterpillars and the larvae of sawflies. We may also find the fruiting stage of a fungus in the shape of small black spots or narrow black lines on discolored parts of the leaf or needle. Often the fruiting bodies develop only on the underside of the needles or leaves.

Premature dying of the foliage of tops, limbs, branches, or twigs may be an indication of local interference with the water supply, the result of partial or complete girdling by porcupines and other mammals (deer, sheep, cattle) or by insects. Leaf or twig inhabiting fungi may, however, locally attack the foliage. Lightning sometimes kills limbs. On old yellow pines, for instance, it is often possible to follow the track a discharge of lightning has taken down the tree by the limbs it has killed on its way. Dead limbs may also be an outward sign of some local trouble in the root system.

Partial or total dying,(reddening, yellowing, premature dropping) of the foliage of single trees may be caused by a variety of agencies, but can, except in the case of needle fungi, almost invariably be traced to some interference with the water supply. If the tree dies in a comparatively short time, the probabilities are that the trouble is located at the butt or in the root system. It is frequently, but not always, a sign of attack by bark beetles.

When the foliage of practically all the trees in a stand is affected at the same time it indicates that the leaves or needles may have been poisoned by smelter fumes or similar gaseous products or killed by fire. It may also mean invasion by insects or that the water supply is in some way out of order.

Disturbance of the root functions caused by drought or by an excess of water in the soil, total or partial destruction of the roots by parasitic fungi, insects, rodents, etc., or starvation of the root tips caused by diseases or by destruction of the living bark above by fungi, insects, porcupines, etc., all tend to cut off the water supply of the tree, the results of which are felt first in the needles or leaves. Certain winter conditions have the same effect (winter injury). Resin flow at the butt of the tree frequently indicates root disease.

When the twigs appear to be diseased examination should be made of the part of the twig where the sound and disease tissues meet. In the case of fungus attack small black spots will often appear on the diseased or dead twig. Sometimes twigs are killed by rodents eating the bark or by deer brushing it off from the underside. If the insects have attacked twigs, their presence is indicated by borings in the bark or wood. All

this applies, of course, not only to twigs but also to leaders; in fact, to all the younger shoots of mature and immature trees. The youngest twig endings of firs may be killed in spring by frost or by insects. Galls on the twigs or branches are caused by insects or by a fungus (see "Diseases of western yellow pine").

Dead branches and limbs in the otherwise healthy crown are always suspicious. The various causes of death have been mentioned under "Premature dying of foliage of tops, limbs, branches, or twigs".

Any alteration of the normal branching system of a tree suggests the presence of some injurious agent. The mycelium of certain fungi spreads into the twigs and even into the branches, causing the formation of "witches'-brooms". These are alterations in the normal system of branching peculiar to every species of tree, and are due to the stimulation caused by the parasite growing in the tissues of the branches or twigs. Witches'-brooms are very common on wild cherries and plums, where they are caused by fungi. Some witches'-brooms (on conifers) are produced by mistletoes. Occasionally, however, their formation is due to excess of nourishment. This is the case with the rather rare witches'-brooms on yellow pine, caused by Cronartium knots, which "girdle" the branch and stop the downward flow of the food prepared in the needles above (see "Diseases of western yellow pine. Pine gall rust"). Other witches'-brooms are caused by mites or insects.

Toadstools or conks (see "Fungi) on trunks and limbs indicate the presence of parasitic fungi and rot in the wood. Until they develop, no outward sign of disease may be visible. Diseases of the trunk or limbs may affect either the sapwood or the heartwood, or both. Disease of the sapwood of coniferous trees is often indicated by a heavy flow of resin from the bark. Resin flow on the butt of the tree points to disease of the root collar and the roots. In cases of this kind we will often find white mycelium under the bark or between the bark scales of the butt. On the trunk where it is not clearly explained by a wound it is always more or less suspicious.

It is well to be on the lookout for any abnormal appearance of the trunk. Cat faces, burls, thick protruding knots, deep knot holes, and abnormal resin flow are always suspicious, and while the decay which they very commonly indicate may not in all cases extend very far, it must not be left out of consideration. Decay very frequently extends down the trunk from dead limbs and dead tops. How far the decay extends through the trunk depends very much upon the species of tree and the species of fungus inhabiting it. The resinous pines suffer least; in spike-topped Douglas firs, white firs and red firs usually one or more upper logs are decayed. In judging a tree every slight swelling and depression on the trunk has to be considered as well as the appearance, color, and quality of the bark. This involves, of course, a thorough knowledge of normal conditions.

Heartrot is not a disease in the proper sense of the word; the heartwood is dead and thus can not be said to be diseased. Heartrots, however, are extremely important from an economic point of view, and are

therefore usually treated as timber diseases. It is often very difficult to diagnose typical heartrot from the outside. In very many cases the tree outwardly appears to be perfectly healthy, while the heartwood is almost completely destroyed. In seemingly sound white fir logs it is often possible to diagnose decay from the Indian paint fungus by the presence of branch stubs which show the characteristic rusty red color produced by this fungus (see "Diseases of balsam firs. Decay").

In our semi-arid mountains many conks, sporophores, or fruiting bodies of the fungi which cause heartrot are produced during fall, winter, or spring, and with exception of the harder, more woodlike forms, are soon destroyed by insect larvae or by squirrels. Careful observation will frequently detect at least some remains of these conks. On incense cedar, for instance, the soft and juicy fruiting bodies are readily destroyed by the larvae of certain insects, many of which then bore into the dead outer bark of the tree. These are eagerly sought after by woodpeckers, which chop them out of the bark. The space formerly occupied by the fruiting body then appears as a cup-shaped depression, which seems to be pierced by innumerable fine shot holes, the burrows of the insect larvae. Insect work on pines is indicated by pitch tubes on the bark, which are characteristic of the attack of Dendroctonus beetles. In such cases the bark should be peeled off here and there to verify the presence of insect work.

Longitudinal rows of small holes in the wood are caused either by woodpeckers or by the roots of mistletoes. The latter kind are particularly conspicuous in the sapwood under the bark. Woodpeckers very frequently bore horizontal rows of holes in the bark, which often heal over, leaving, as an outward sign, peculiar protruding ridges.

The weakening of a tree by one injurious agent very often opens the road to another, which would not have been able to attack the sound tree. Cankers on the trunks of white fir, caused by mistletoe, are very commonly connected with stringy brown rot, caused by the Indian paint fungus. Certain insects almost invariably follow injury by fire. Insects and parasitic fungi or mistletoe very often work in this way for each other and in collaboration.

All the injurious agencies mentioned can combine. The same tree might suffer at the same time from needle miners, needle disease, mistletoes, root diseases, bark beetles, drought, etc. Different diseases will also attack the same tree at different stages of its life.

FUNGI

The majority of forest tree diseases are caused by fungi. Fungi are very simple plants which cannot live on the simple food elements of the soil and air and build up complex organic matter, as is done by the green plants with which we are familiar, but must have organic matter already prepared in order to sustain life. This, they find in the material built up by green plants, hence they may attack living plants, or dead portions of such plants, or any dead vegetable matter. Some live on animal matter but these do not concern us. The development of fungi is dependent upon a

supply of oxygen of which there is always sufficient in the air, a certain amount of moisture, a suitable range of temperature and the necessary food substances. The maximum and minimum of these requirements vary widely with different fungi.

The fungi plant consists of very fine threads (hyphae) which are invisible to the naked eye unless they occur in mass. Individual hyphae require magnification by a compound microscope. Collectively the hyphae are termed mycelium. The hyphae usually live in the tissues of the substance on which the fungus is growing. The fruiting bodies or sporophores which vary in size from so small as to be invisible to the naked eye except in a mass to quite large and conspicuous appear on the surface after hyphae have developed vigorously. The fruiting bodies bear the spores, which are microscopically small reproductive bodies of relatively simple structure. The spores being very light, are borne about by air currents. If they light in a suitable place under proper conditions germination takes place and hyphae develop.

Fruiting bodies vary greatly in size and shape. They may appear on leaves, needles, or twigs as small black or colored spots or lines and on trunks, logs, or branches as brackets (then popularly termed conks), crusts, or toadstools.

Various broad groups of fungi are confined in their activities to certain parts of the tree. A heartwood destroying fungus, for example, will not attack the needles, while a needle fungus will never attack the heartwood. This is even carried farther in that some decays are confined to the roots and butt of a tree only, while others may extend throughout. Certain fungi only attack certain trees while others are found on a wide range of hosts.

Wood destroying fungi attacking the heartwood of living trees are very common and at the same time cause huge losses in the merchantable volume of commercial species. The hyphae of wood destroying fungi living within the wood feed on the various substances composing the cell walls, neglecting others, with the result that the cell walls are broken down, the wood being thus greatly weakened and more or less destroyed. It is the breaking down of the wood and the change in its physical and chemical qualities that is termed decay. The degree of decay is determined by the energy of growth of the fungus, the length of time the fungus has been at work, and the type of wood it attacks. Some fungi attack many different kinds of wood, while others are limited in their choice. As a rule, wood-destroying fungi attack only the heartwood in living trees, but after the trees are dead the sapwood is quickly destroyed. The fruiting bodies, usually quite large, are found on the trunk, on the branches, or on the ground nearby (coming up from a decayed root) in the form of conks, crusts, or mushrooms. They are not developed until the hyphae have been at work for some time, consequently the presence of fruiting bodies indicates serious decay. Pores, gills or spines are normally found on the under surface of the fruiting bodies and here the spores are produced. The spores can not infect another tree through the unbroken bark but must fall on heartwood or exposed dead wood connecting with the heartwood. Such places are offered by spike tops, broken tops, dead branch stubs, fire scars, lightning wounds, frost cracks, etc.

MISTLETOE

Our forests have perhaps no more widely distributed parasitic enemies than the mistletoes. Two kinds of mistletoe grow on forest trees; one belonging to the genus Phoradendron, an example of which is the ordinary Christmas mistletoe, the other belonging to the genus Razoumofskya (Arceuthobium), and confined to coniferous trees. Phoradendron is the larger of the two and may have leaves, as on oak, or be leafless, as on incense cedar. Its berries are round, white, or pink, and contain a seed imbedded in a thick, extremely sticky glue. The seeds are carried by birds from one tree to another, adhere to the bark, and germinate. The Phoradendrons are light-seeking, and therefore grow high up in the tree. Razoumofskya is smaller. The thin and brittle stems stand out from the branch they grow on like a small yellowish brush. The oval berries hang on erect stems, and are light green in color. In ripening they develop a considerable inside pressure, which increases until the slightest disturbance is enough to make them explode and eject the seed with some force. These are scattered about at random, and many perish for lack of food; others stick to the bark of young branches and twigs and germinate. The Razoumofskya species are more tolerant of shade than the Phoradendrons.

Mistletoe seeds of both groups can germinate under normal conditions almost anywhere, but they can penetrate only the young, thin bark of those hosts to which they are adapted. For example, Razoumofskya seeds (embryos) thrown from a yellow pine onto a twig of an oak standing beneath it can germinate, but can not penetrate the bark and enter the living tissue. The same seed landing on a young yellow pine twig, however, develops a small rootlet, which perforates the bark. From this rootlet are developed other roots (cortical roots) running up and down in the bark of the twig, and from these again so-called sinkers are started - that is, roots growing straight down to the wood. In the meantime, the mistletoe plant develops on the outside of the twig at the cost of the host tree.

The damage the mistletoes of both groups cause to their host consists less in depreciation of timber than in the attack on the vital organs of the host. They belong to the higher plants which are characterized by roots, stems, green foliage, and flowers. Parasitic life has robbed the mistletoes of their independence. They are unable to take raw food from the soil; their root system is much reduced and has adapted itself to the function of tapping the tissues of their hosts. The foliage of the Razoumofskyas is reduced to small scales and they contain very little green pigment with which to assimilate carbon dioxide from the air. They depend, therefore, upon their host not only for water, but also for the greater part of elaborated food. The Phoradendrons, on the other hand, generally possess green leaves, or, at least green stems. They elaborate their own food and normally draw only water and raw food from the host.

The effect of the mistletoe on its host is chiefly that of a parasite tapping the saps and girdling the branch it grows on. The irritation of the cambium by the roots of the mistletoe results in a considerable swelling of the branch at the point of attack. The wood of such swellings if very characteristically marked by longitudinal rows of small holes made by the sinkers. The holes caused by the sinkers of Phoradendron are particularly conspicuous.

Mistletoes do not often kill outright. Girdling by Razoumofskya can even stimulate for quite a time the growth of the branches and leaves above the point of attack. This luxuriant growth, however, is of little benefit to the tree. The food prepared in the excess foliage above the mistletoe serves to nourish the mistletoe plant, and barely sufficient food is allowed to go below to the roots to keep them from starving. In many cases the attack ends in the death of the branch or limb, and when many limbs are affected in the death of the tree. Razoumofskya very often causes a formation of witches brooms. Large formations of this kind, often resembling richly branched, low-hanging limbs, with profuse foliage, are very conspicuous and common on yellow pine, lodgepole pine, and Douglas fir Phoradendron sometimes lives for a great many years and then causes swellin and deformations, for instance on trunks of incense cedar, where the parasite has been known to live for more than 220 years. As the rather brittle mistletoe shrubs break off easily, rarely lasting more than 10 years, new shrubs are formed from buds breaking through the bark of the host, as long as the bark is not too thick. In cases where incense cedar mistletoe, for instance, has grown to a high age with its host tree, the bark of the latter becomes so thick that it cannot be pierced by the young mistletoe sprouts. The mistletoe then lives without green parts, consisting only of cortical roots and sinkers, and depending altogether for all food on its host. In this state it acts very much like a fungus, which also is unable to elaborate its own food and has to rely upon other plants.

Phoradendron rarely attacks young trees. Razoumofskya, on the other hand, very often does considerable damage to young western yellow and lodge pole pine. If the stem or leader is infected, the young tree is killed in the course of time, or at least prevented from developing a straight, clean bole.

The Razoumofskyas, also called false mistletoes, are of the greatest importance since they attack nearly all of the commercially valuable conifers and greatly reduce their normal rate of growth. An important characteristic of the false mistletoes is that each species with the exception of rare instances of no practical importance, is confined to a single host. Furthermore, Razoumofskya dies after the tree on which it is living is cut, it spreads slowly through the stand and infections as far as known, can not occur through bark more than four years old. False mistletoes rarely o never infect trees through wounds in the way fungi do. The importance of these points will be brought out in the discussion on control.

DISEASES OF DOUGLAS FIR

Decay

The loss through decay in stands of Douglas fir in the Pacific Northwest is very large. While some overmature stands are relatively sound a loss of 20 per cent in such stands is not uncommon. In certain cases the cull figure may reach 50 per cent or more, so high that in timber on difficult ground it becomes impossible to log at a profit. It is only in young stands of second growth that Douglas fir is uniformly sound.

All but a negligible portion of the decay in Douglas fir can be attributed to four species of wood destroying fungi. They are the ring scale fungus (Trametes pini), the velvet top fungus (Polyporus schweinitzii), the quinine fungus (Fomes laricis) and the rose colored Fomes (Fomes roseus). Of these the ring scale fungus is by far the most destructive. An analysis of a number of trees in a defective, overmature stand showed that of the total cull of 45 per cent from decay, 39 per cent was caused by the ring scale fungus, 2.5 per cent by the velvet top fungus, 2 per cent by the quinine fungus, and 1.5 per cent by the rose colored Fomes.

The ring scale fungus causes decay commonly known as conk rot in the Douglas fir region. The decay is not confined to any one portion of the bole. In the typical stage the wood is riddled with small white pits or cavities separated by apparently sound wood. The incipient stage is particularly striking. It appears as a pronounced reddish purple or olive purple discoloration, gradually becoming fainter as the distance from the typical decay increases until it is lost entirely. The color is often most pronounced in the outermost heartwood just where it joins the sapwood. In some cases it appears brownish against the red or yellow heartwood. Vertically the discoloration may extend 10 feet or more in advance of the cellulose pits but radially this is limited to two or three inches. The discolorations described are often bounded by a narrow zone of pronounced red color.

Sporophores or conks are very common in overmature Douglas fir stands. These perennial fruiting bodies issue from the tree through knots. They vary in size and shape from bracket-like to hoof-shaped. The upper side is a dull grayish or brownish black, rough, and with concentric furrows parallel to the light brown margin. The under side is a grayish brown or rich brown color with large, irregular pores. The substance of the sporophore is corky or punky.

Practically all cull due to conk rot results from infections entering through dead branch stubs or knots. Wounds caused by mechanical injuries are of no importance as infection points.

Conk rot is relatively easy to detect. Sporophores occur abundantly. As a rule only negligible decay develops in a tree before a sporophore appears, or if not a sporophore, at least a swollen knot or blind conk, as it is otherwise known. A swollen knot is the initial stage of a sporophore in which the substance forming the conk is pushing its way through a knot and forcing out the bark. Hence it is just as good an indication of the presence of decay as a sporophore. Often the sporophore never develops beyond this stage. Chopping into one of these swollen knots reveals a brown punky substance, the same as in a fully developed sporophore. The development of swollen knots and sporophores follows rather closely the progress of the decay in the heartwood. So it is possible to pick out rather accurately trees affected with conk rot in a stand. When high up in a tree among the branches, swollen knots are not easily seen, but if overlooked there it does not make so much difference in accuracy of an estimate since the scale of the top logs is relatively insignificant in the total.

It is not only possible to pick out the decayed trees but it is also feasible to judge with some exactness the normal extent of conk rot. In a number of trees studied it was found the decay usually extended about 20 feet beyond the last sporophore and about 9½ feet beyond the last swollen knot. Of course individual examples varied considerably from the distances given; but these figures are a good average and have checked well with the writer's observations since. Where only one sporophore or swollen knot occurs the decay is localized, resulting in little cull. By studying felled trees and then watching infected logs through the mill it is possible to get these limits to fit any local conditions.

The estimate of the amount of defect in logs* or felled timber is much more simple than with standing trees. Knots can be tested carefully for signs of rot and where bucked the ends of the logs can be examined for typical decay or the discolorations of incipient decay. It is not at all difficult to judge quite accurately the extent of conk rot in a felled Douglas fir by chopping into the knots to reveal the brown punky substance of the blind conk.

The quinine fungus has a large, conspicuous, whitish perennial sporophore not at all common on living trees. The substance of the sporophore is white, soft, and cheesy when young and rather crumby and chalky when old and dry, with a very bitter taste. The pores are small. The decay, which is not confined to any particular portion of the heartwood in the trunk, is a crumbly brown rot easily recognizable by its mycelium felts or sheets (i.e., closely woven masses of fungus hyphae).

The incipient stage of this decay is very difficult to detect and even when the wood has been decidedly weakened, the extremely faint, brownish discoloration is barely discernible.

This brown trunk rot enters the tree through branch stubs and wounds. The decay is rather hard to judge in living trees. Sporophores are rare but when they do occur are very conspicuous and not readily overlooked. Furthermore, a single sporophore indicates extensive decay in a tree. However, the total loss caused by this rot is insignificant.

The velvet top fungus causes a red-brown crumbly butt rot which breaks up more or less into cubes. The mycelium felts are very fine and inconspicuous. The decay rarely extends higher than the first 16-foot log and the rot column is normally cone-shaped. The incipient decay is first evident as a faint yellowing or browning of the normal heartwood. At this stage the wood is already seriously weakened. The sporophores or conks appear either on the butt of the infected tree or on the ground near by and are annual. They are rather large with a light brown upper surface, olive green or dirty green under surface and a cheesy consistency when young, but when old and dry are a dark rust brown and corky. Sporophores on the ground have a short, thick stalk.

---

*For detailed instructions for scaling out decay the reader is referred to the article by E. I. Kerr entitled "Log Scaling in the Douglas Fir Region", which appeared in The Timberman for April 1920.

Most red-brown butt rot enters the trees through wounds and of these wounds fire scars are in a large majority. Consequently the best clue to the presence of this decay is fire scars. The large majority of fire-scarred trees become infected through the scar, so it is possible to judge the relative amount of the rot by fire-scarred trees in the stand, considering each fire-scarred tree as infected. Even though a scar has been healed over for a long time it can often be detected by the variation in the appearance of the bark over the healed wound. This appearance is hard to described but not difficult to judge after a little experience. Swollen or churn butts usually indicate red-brown butt rot since the abnormality is commonly the result of a fire scar or other wound long since healed.

The rose colored Fomes causes a yellow-brown crumbly decay with mycelium felts much less conspicuous than those of the quinine fungus. Furthermore, this decay is usually confined to the upper portion of the trees in connection with dead tops and in many infected trees the decay does not extend into the merchantable portion of the tree. The sporophore of this fungus is easily recognized by the delicate rose color of the under surface. The pores are small. The upper surface is rough, hard, and black.

Trees become infected with yellow-brown top rot through dead branch stubs, dead tops, and various wounds. The decay is rather hard to detect in living trees. While sporophores are not uncommon they are so high up in the trees as to be easily overlooked and are often completely hidden by the branches. However, the amount of loss through this decay is very small in the aggregate.

Mistletoe

The Douglas fir mistletoe (Razoumofskya douglasii) is not found north of the Umpqua-Rogue River divide, west of the summit of the Cascades, but the parasite is very severe in eastern Washington and eastern and southern Oregon.

This mistletoe is very easily overlooked, being exceedingly small and inconspicuous, but the characteristic huge, pendulous or "weeping willow" like witches brooms caused by parasite are very striking. In addition, long, spindle shaped burls result from infections on the trunk from which the aerial portions of the mistletoe plant may have entirely disappeared. Such burls are worthless for lumber.

Spike tops commonly result from infection and many mature and overmature trees ultimately die from the effects of the mistletoe. The rate of growth of infected trees is considerably reduced. A comparison of infected and uninfected 100-year old trees in eastern Oregon showed that height growth of the infected trees was reduced by 15 per cent and diameter growth by 20 per cent.

Needle Blight

Needle blight, caused by a parasitic fungus (Rhabdocline pseudotsugae), is essentially a disease of trees in the sapling stage, that is up to about the 30-year age class. This disease when severe kills all needles except the youngest on the ends of the twigs, causing them to turn brown and drop off. The fruiting bodies which occur on the undersurface on either side of the middle nerve of the needle appear as small, brown, elongated discs or cushions, and may be partly covered by the ruptured epidermis (outer layer of the needle). They are usually fully developed by early summer.

The infected needles fall at all seasons of the year, owing to the fact that a portion of them are not as seriously infected as others and may remain on the tree for an indefinite period. A slight jar is often sufficient to cause the needles to fall in a shower. Trees which have been subject to the ravages of the fungus for several seasons are almost entirely defoliated and either die or merely exist for an indefinite period without making any perceptible growth. The greatest damage is done in close, pure stands. Douglas fir in mixed stands is not so frequently attacked.

Canker

Douglas fir canker, caused by the fungus Phomopsis pseudotsugae, has not yet appeared in North America, but the disease has such serious possibilities that it seems advisable to discuss it briefly.

Of late years there has been considerable planting of Douglas fir in Great Britain. Recently a parasitic fungus has been found attacking the plantations. The disease is becoming increasingly severe each year. The fungus attacks the main stem, either killing the tree outright or causing the death of the top, greatly retarding growth. The disease spreads directly from infected trees to sound ones.

An idea of the damage resulting may be obtained from the fact that in Scotland a 6 to 8 year old plantation when examined in the spring was found to have had about half the trees killed by this disease. The dead trees were removed, burned, and then the spaces replanted. By fall 20 per cent of the trees were showing signs of attack, including some planted in the previous April. Just what the fungus can do on large trees is problematical. Mature Douglas firs, except as ornamentals, are practically unknown in Great Britain.

Since the disease spreads directly from infected trees to sound ones it is very difficult to control, and furthermore, a long period elapses between infection and the first obvious signs of disease. If this parasite is introduced anywhere into the Douglas fir regions of North America a widespread, disastrous, and probably uncontrollable epidemic would probably result. It is axiomatic that parasites often become exceedingly destructive when introduced into regions where they do not naturally occur.

DISEASES OF WESTERN HEMLOCK

Decay

This species, also known as west coast hemlock, is subject to a large amount of decay, practically all of which is caused by the Indian paint fungus (Echinodontium tinctorium). The loss caused by this fungus may amount to 30 per cent or more in a given stand.

The perennial sporophores of this fungus are quite conspicuous. They range from a few inches to a foot or more in width and are hoof-shaped. The upper surface in old specimens is black, dull, rough, and cracked. The under surface is grayish in color, level, and is thickly set with hard coarse spines. In younger specimens the upper surface is lighter in color and the under surface is light grayish to whitish with somewhat labyrinth-like pores before breaking up into spines. The interior of the sporophore is a striking rusty red color and this rusty color is often seen in the decayed wood. The Indians made a pigment from the substance of the sporophores. The sporophores are formed on the underside of dead branch stubs and normally the rust color runs through these stubs or knots into the decayed heartwood. The sporophores are commonly located on the middle or lower middle section of the trunk and are developed quite abundantly.

The typical decay is reddish brown to brownish yellow in color, sometimes with rust colored areas. In the last stages of decay the heartwood is completely broken down resulting in large hollows particularly in the butt logs. The wood is stringy and fibrous and from this stage the decay takes its name of stringy brown rot. The incipient decay is not easy to detect since the initial discoloration closely approximates the pale brown, slightly tinged with red color of the normal heartwood. The wood first assumes a faint yellowish color which is sometimes intensified by the presence of small hardly discernible brownish areas. These areas later develop into the typical decay. The extension of the incipient decay beyond the typical decay varies from one to five feet.

It is highly important that all incipient decay be excluded from logs or lumber. When wood with incipient decay is milled the boards when dried check badly or fall apart completely. For the sake of safety lumber should be trimmed 2 feet beyond the last recognizable yellowish discoloration in order to eliminate all incipient decay.

By far the greatest percentage of infections of stringy brown rot in hemlock enter through branch stubs, while the small minority remaining can be traced to various injuries, such as broken tops, sapsucker injury, frost cracks, logging scars, fire scars, lightning scars, and others.

There are certain more or less definite indications of stringy brown rot in living trees. A sporophore normally indicates considerable decay. An average sized sporophore on the butt 16 feet of the trunk indicates that the first two 16-foot logs are cull. A sporophore higher up on the bole probably means that the entire main portion of the bole is unmerchantable. A tree with several sporophores some distance apart is completely unmerchantable.

Trees without sporophores are not necessarily free from decay. Old sporophores may die and fall off but in this case a discolored spot on the bark or the hole left by the decayed branch may be seen. Furthermore, the old sporophores can sometimes be found on the ground close to the tree. In its more advanced stages, stringy brown rot may be detected by pounding on the tree. Rusty knots or branch stubs are excellent signs of decay. This rusty reddish color in the branch stubs or knots, the same color as the substance of the sporophore indicates typical decay in the heartwood. It does not occur in every dead branch stub over the decayed area but normally occurs in some of them and can be readily exposed with an ax. In big timber this method of detection is principally of value for felled trees.

The ring scale fungus sometimes causes decay in hemlock, but the total loss caused by this fungus is trifling. Red brown butt rot caused by the velvet top fungus does occur now and then but the aggregate loss is very small.

Mistletoe

Hemlock mistletoe (Razoumofskya tsugensis) is quite common. The parasite causes witches brooms and spindle-shaped swellings on infected stems and branches of trees of all ages. The growth of infected trees is retarded. This mistletoe is particularly abundant and severe in Alaska.

DISEASES OF SITKA SPRUCE

Decay

There is much less loss from decay in Sitka spruce than in Douglas fir or hemlock. As a rule this species is quite free from decay up to an age of 200 years.

The most serious wood destroyer on Sitka spruce is the ring scale fungus which may attack any part of the bole, causing the typical decay described before. The incipient decay appears as a reddish discoloration. The decay enters the tree principally through the old branch stubs.

The velvet top fungus causes a butt rot. No description of the typical stage is necessary. The incipient decay first becomes evident as pale yellow to lemon yellow streaks or spires extending longitudinally beyond the light yellowish to reddish brown discoloration which characterizes the more visible incipient decay. In the latter stage a softening of the wood is apparent, but the wood is seriously weakened even in the first stage.

The red belt fungus (Fomes pinicola) which is most common on snags, windfalls, and other debris, also causes a butt rot in living trees. The perennial fruiting bodies which are rather large and vary in shape from hoof-shaped to shelf-like are characterized when young by a chestnut brown to reddish band around the margin of the upper surface and a creamy white

under surface with numerous fine circular pores. The typical decay is light reddish brown in color, crumbly and brittle, breaking up into rough cubes with mycelium felts in the cracks. The mycelium felts are not so large nor abundant as those formed by the quinine fungus.

Needle Cast

This needle disease is characterized first by a browning of the individual needles. Next the fruiting bodies of the parasitic fungus (Lophodermium) causing the disease to appear as black lines following the middle nerve on the under side of the needles. Infected needles are invariably killed and drop off, but the degree of infection varies. Sometimes only occasional needles are diseased, at other times most of them may be killed except the youngest needles on the ends of the twigs. The fungus usually attacks the lower branches of saplings and small poles, mature trees being free from infection.

Needle Rust

A rust fungus (Melampsoropsis ledicola) attacks young needles of saplings. Infected needles become yellow while on the under surface small elongated areas surrounded by a white membrane and filled with an orange red powder appear. This powder is composed of innumerable spores. The diseased needles soon drop off. Little injury results as infection is usually rather light.

DISEASES OF BALSAM FIRS

Decay

In this group of trees is included white fir (Abies concolor), lowland white fir (A. grandis), silver fir (A. amabilis), noble fir (A. nobilis), and red fir (A. magnifica and A. shastensis). The balsam firs are quite susceptible to decay, particularly lowland white fir and white fir.

White fir is very badly affected with stringy brown rot caused by the Indian paint fungus. The other species are also attacked but in a very much lesser degree. In the Blue Mountain region of eastern Oregon white fir is so badly infected that a cruising rule often used is to cull all trees over 18 inches diameter breast high completely and those less than this size are reduced 25 per cent. In other localities losses of 25 per cent or more in mature and overmature stands are common. On some operations white fir is not cut because it is so defective.

The characteristics of the sporophores on white fir are quite similar to those described for western hemlock. The incipient stage of this decay is first indicated by light brown or golden tan spots or larger areas of discoloration in the light colored heartwood which may be accompanied by small but clearly distinct radial burrows resembling somewhat

very shallow insect burrows without the deposit of excrement. These burrows are not easily detected on cross section. Next rusty reddish streaks appear following the grain. Throughout this stage the wood appears firm and strong, but in reality is so greatly weakened that boards may separate along the annual rings when dried. The above colors intensify, the wood becomes soft, showing a decided tendency to separate along the springwood in the annual rings, and finally the typical stage is reached, in which the wood is brown with pronounced rusty, reddish streaks, and becomes fibrous and stringy. Hence the name stringy brown rot applied to the decay. The incipient decay usually extends from two to six feet beyond the typical decay and should be treated as cull.

Much of the stringy brown rot in white fir enters through wounds and of these fire scars, followed by frost cracks and lightning scars are the most common infection points. Some infections enter through branch stubs.

Sporophores are the best indications of decay and for practical purposes signs of stringy brown rot in white fir are similar to those in western hemlock. Rusty knots are common. In scaling if the ends of a log do not show decay, from three to four feet on each side of the rusty knot should be considered cull.

Other decays found on the balsam firs in this region are of little importance as a rule. The ring scale fungus and the velvet top fungus are sometimes found. Red fir is often attacked by the sulphur fungus (Polyporus sulfureus) with considerable resulting loss. The decay is quite similar to that caused by the quinine fungus. However, at present red fir is rarely cut.

Mistletoe

The fir false mistletoe (Razoumofskya occidentalis abietina) is frequently quite severe, particularly on white fir (Abies concolor). The parasite causes witches brooms, but not so large as most of the other Razoumofskyas. One common result of trunk infections is the development, on mature and overmature trees, of large barrel-shaped swellings on which later the bark breaks forming a large open wound or canker. Besides rendering the affected portion of the tree wholly unmerchantable, the swelling, composed of abnormal tissue, markedly weakens the tree, while the open wound is commonly infected by the Indian paint fungus causing stringy brown rot. White fir trees broken off by wind immediately above or below the swelling or in the canker itself, are a common sight in mistletoe infected stands. Furthermore, most of the trees with these cankers are badly decayed.

On red fir (Abies magnifica or A. shastensis) the mistletoe commonly kills an infected branch before a witches broom of any size develops. These dead branches are very striking in a heavily infected stand.

Needle Cast

This disease of young firs kills all needles except the youngest on the ends of the twigs, causing them to turn reddish gray and finally to drop off. The lower parts of the tree suffer most. When severe the disease results in almost complete defoliation. The fruiting bodies of the fungi (Hypodermella abietis-concoloris or Hypoderma robustum) appear in long, black streaks following the middle nerve on the underside of the needles.

Needle Rust

This disease is caused by several different rust fungi so similar in appearance that they can be distinguished from each other only with difficulty. The fruiting bodies appear on the underside of the younger needles, that is, needles of the present or previous seasons growth, as small white or faintly orange colored columns from one-sixteenth to one-eighth of an inch high standing erect from the needle. Then the membrane of the column ruptures, disclosing the orange red spores within. Infected needles die and drop off.

Yellow Witches Broom

A bright yellow witches broom is sometimes found on the branches of white and red fir. Such brooms are caused by a rust fungus (Melampsorella elatina), which develops its fruiting bodies, somewhat similar in appearance to those of the other needle rusts on the deformed needles.

DISEASES OF WESTERN RED CEDAR

Decay

As a rule this species is relatively free from decay and there are few definite figures on the small amount of cull in different localities where the tree is commercially important.

A common butt rot is caused by the brown cedar Poria (Poria weirii). The action of the fungus results in a separation of the annual layers of the wood in the earlier stages of the decay, giving the disintegrated wood a laminated appearance. The final stage is a brown, crumbly rot. The sporophores are brown in color, thick and crust-like.

A red-brown butt rot probably caused by the velvet top fungus is not uncommon, particularly on the west slope of the Cascades.

A decay similar to the dry rot of incense cedar has been observed on several occasions, but this is rare.

In northern Idaho where western red cedar is not so thrifty and rapid growing as in western Washington and Oregon the ring scale fungus sometimes causes considerable damage. From 2 to 30 per cent of rot, principally caused by this fungus, has been found in trees ranging from 10 to 45 inches at diameter breast high, the amount of decay increasing with the size of the trees.

Leaf Blight

This very common disease is caused by a parasitic fungus (Keithia thujina). The leaves of trees of all age classes are attacked, the severity of the attack depending upon the humidity of the site. The lower branches of young trees from 20 to 50 years of age, when growing in dense stands on low ground, often appear at a distance as though scorched by fire. The fruiting bodies appear on both the surface of the leaves as brown or black spots or cushions, more or less circular or elliptical in outline, and at first are covered by a flap of the outer membrane of the leaf. In the fall the young infected leaf-twigs drop off leaving the branches quite bare. On leaves remaining attached to older twigs, the presence of the fungus is readily determined by the fact that the fruiting bodies fall out leaving a pit that almost perforates the leaf. These leaves turn an ashy gray.

The parasite primarily attacks seedlings and young trees. Seedlings under four years of age are killed quickly, often in a single season. The foliage of the upper crown of large forest trees may be generally infected but never to the same extent as the leaves on branches near the ground.

This fungus, in common with all needle or leaf inhabiting fungi, more or less retards the growth of infected trees, particularly in the younger age classes.

DISEASES OF PORT ORFORD CEDAR

This species is quite free from disease of any kind. The loss from decay in merchantable stands is very small. A red brown butt rot is found rarely. The ring scale fungus occasionally attacks the heartwood but as is the case with all the cedars the striking discoloration of the incipient stage is lacking.

DISEASES OF INCENSE CEDAR

Decay

The heartwood of incense cedar is commonly rendered completely worthless by dry-rot or pin-rot caused by the fungus Polyporus amarus. An idea of the amount of timber rendered unmerchantable by this dry-rot may be obtained from the fact that in cruising, so common is the defect

that it is the usual practice to cut estimates of the species from 30 to 50 per cent on account of it. This leads to a distinct prejudice against incense cedar on the part of both the lumberman and the forester and the tree is classed as an "inferior" species.

The sporophores, which last for one season only, even at best are not at all common. During certain years sporophores seem to be very rare. They most commonly occur in the summer, and especially in the fall, but occasionally are found at other seasons. The sporophores issuing from knot holes, at first are soft and mushy and then become tough and cheesy. They are bracket shaped with rounded tops or half bell shaped. When fresh the fruiting bodies are smooth and tan in color on top with a bright sulphur yellow underside, but they become brown with age. Although sporophores are rather rare, an accurate indication of the place formerly occupied by a sporophore is supplied by the shot hole cup. These shot-hole cups appear as cup-shaped depressions below a knot, the depression being riddled with numerous fine holes. At first they have the color of the freshly opened bark of the tree but later become weathered and gray with age. They are formed in the following manner: The soft fleshy or cheesy sporophores issuing through knots are usually soon eaten by squirrels and larvae or grubs of insects. Some of these larvae then bore into the bark of the tree where they are sought after by woodpeckers which chop out a cup-shaped depression in the bark, corresponding to the place formerly occupied by the sporophores. This depression is riddled with what appear to be numerous fine shot holes with burrows of the insect larvae.

The typical decay consists of vertically elongated pockets varying in length from one-half inch to about a foot which are filled with a brown crumbly mass and the line of separation between the sound and decayed wood is very sharp. In some of these pockets small cobweb-like or felt-like masses of white mycelium occur. The pockets are separated from each other by what appears to be sound wood although in some cases streaks of straw colored or brownish wood may extend vertically between two pockets. This is especially noticeable between young pockets. At times the mature pockets may be several feet long and rather broad; this type always occurs in connection with healed-over wounds, particularly healed fire scars in the butt of the tree.

The pockets of incipient decay are at first firm and very faintly yellowish brown. This color deepens slightly and the wood becomes somewhat soft. The incipient decay extends but a short distance vertically in advance of the typical decay and a distance of two feet beyond the last visible evidence will usually exclude all decay. The incipient decay is only faintly apparent, occurring as it does in pockets with the color in the very earliest stages differing but slightly when at all from the normal wood. An occasional pocket may occur several feet in advance of the main body of decay. The wood even in an incipient pocket is decidedly weakened although the intervening wood is apparently not affected.

The purplish coloration of the heartwood so commonly found in freshly cut incense cedar and which fades within a few days on exposure to light and air is not a stage of incipient decay. Cedar colored in this way is absolutely sound.

Fire scars are responsible for most of the dry-rot in incense cedar. About 80 per cent of the total volume of cull results from infections through such wounds. Knots or branch stubs are next in importance, being responsible for some far-reaching decay causing considerable loss, but most of the infections through knots are confined to the immediate vicinity of the knot and little cull results. Very few infections enter through lightning scars, frost cracks, or dead tops.

During the earlier years of their life incense cedars are relatively free from dry-rot. Suppressed, that is slow growing, trees become subject to extensive dry-rot resulting in considerable cull at about 165 years while dominant trees, that is thrifty, fast growing individuals, remain relatively free from such loss until about 210 years of age.

In order to handle incense cedar properly on logging operations the outward indications of hidden defect should be thoroughly understood; a badly fire scarred stand will have a relatively high per cent of dry-rot. A sporophore or shot-hole cup on a tree always indicates that there is extensive decay in the heartwood. As a rule these occur on the trunk at about 15 to 30 feet above ground level and the heartwood is always unmerchantable from the ground level to a height of 10 to 50 feet above the sporophore or shot-hole cup.

A scaler should keep in mind the relation of wounds, particularly those caused by fire, to dry-rot in the tree. A large pocket of dry-rot occurring close to a healed wound, especially fire scars in the butt of the tree, usually diminishes in area as the height increases and ends in a point immediately above the termination of the healed fire scar it is following. For example, in case a butt log shows a large pocket of decay adjacent to a healed fire scar on its basal cross section, while the top cross section is absolutely sound, it is safe to assume that the decay will end about 6 feet from the base of the log, or in exceptional cases a length of 10 feet may be attained.

Particular care should be used in scaling butt logs with an open fire scar at the base. Dry-rot of any seriousness is rarely found in the dried out wood around an open fire scar. The base of such a log is nearly always absolutely sound; the top may show the entire heartwood unmerchantable; it is quite possible then for the scaler to judge the decay as extending half way down the log from the top, giving the lower half full scale and judging the upper half unmerchantable. But invariably the dry-rot will commence just at the top of the fire scar and almost immediately spreads out over the entire radius of the heartwood. In other words, in a log with an open fire scar showing on the base but otherwise sound and with pockets of dry-rot in the top end, the decay should be considered as beginning at about the top of the fire scar and extending from there to the upper end of the log in practically the same degree and radial extent with relation to the heartwood as is shown on the top end.

Decay in incense cedar is sometimes caused by the ring scale fungus. The rot is usually localized around knots or healed scars and is not accompanied by the conspicuous purplish red discoloration characteristic of the incipient stage of this decay in Douglas fir. The decay is not apparent until the white cellulose pockets are formed. Sporophores are rarely ever found. In the aggregate the resulting cull is of no commercial importance.

A red-brown butt rot similar to that caused by the velvet top fungus and which may be caused by the same fungus occurs occasionally. On the whole the resulting loss is trifling.

Mistletoe

Incense cedar mistletoe is a leafless Phoradendron (Phoradendron libocedri). The large mistletoe plants hanging down from the branches or top are quite conspicuous, their dark green color contrasting strongly with the yellow green foliage of the tree.

This mistletoe is most commonly found on mature and overmature trees, infecting trunks and branches. Conspicuous spindle-shaped or barrel shaped swellings several feet in length result from trunk infections. The wood in these swellings is worthless for lumber. The branch infections with the pendulous mistletoe plants are most conspicuous, however. As a rule the mistletoe becomes more severe as the trees grow older with the result that dead limbs and spike tops are numerous. It is not uncommon to find trees with little foliage left supporting a large number of mistletoe plants. Ultimately severely infected trees may die.

Rust

Two distinct forms of this disease which occur on incense cedar of all ages are caused by the same fungus (Gymnosporangium blasdaleanum). Both forms may appear on the same tree.

In early spring many of the small sprays of incense cedar trees from sapling to pole size appear slightly discolored. On the under side, or more rarely, the upper side of the green, flat, scale-like leaves a number of small, hairy, brown to brick-colored tufts or cushions appear. When mature, these cushions become gelatinous during the spring rains and finally unite with neighboring cushions to form rather conspicuous, slimy, and light orange colored masses which later dry up to a thin film and finally drop off. By this time the sprays have turned quite yellow. Later they die.

The small cushions on the leaves are the fruiting bodies of the fungus, composed of winter spores. These germinate in the spring and produce a second kind of spores which infect the western service berry. In a short time small, orange-colored, cup-shaped fruiting bodies appear on the leaves, young stems, and fruits of the service berry and the spores produced in these then infect the incense cedar.

Witches brooms which are very common are also caused by this rust fungus. Only the smaller sprays, apparently, are killed. If these alone are attacked no deformation of the host is noticeable. When an older twig is infected, however, the result is a local change in the branching system. The resulting witches brooms are numerous and conspicuous. The cushion-like fruiting bodies develop on small sprays at the base of these. Witches brooms are found even on small saplings. At a distance the witches brooms might be taken for plants of the incense cedar mistletoe. The latter, however, always hang down in thick clusters while the bushy witches brooms stand more or less erect.

DISEASES OF WESTERN LARCH

Decay

The most important decay of western larch is caused by the quinine fungus. The rot occurs throughout the trunk. The ring scale fungus also causes some cull. Furthermore, swollen knots on living trees indicating the presence of decay caused by this fungus are often so very large and numerous as to make the trunk of a badly decayed tree very irregular in outline and almost cankerous. Sporophores or conks are also common. The velvet top fungus again is responsible for a typical butt rot.

Mistletoe

Larch mistletoe (Razoumofskya laricis) is very destructive and is responsible for the deterioration of many stands of larch in eastern Oregon and Washington.

The mistletoe attacks trees of all ages from seedlings to mature trees. The type of infection working the greatest injury in the shortest time is the formation of conspicuous witches brooms on the branches. The extra weight of the brooms together with the accumulated debris causes the branches to be readily broken off by wind or a heavy load of snow, thus depriving the tree of its normal food supply.

If not entirely suppressed or killed, trees attacked in early life seldom produce a good grade of merchantable timber. All trees seriously infected show poor health and reduced diameter or height. A comparison of infected and uninfected 100 year old larches in eastern Oregon showed that the average height of infected trees was 45 per cent less, and the diameter growth 41 per cent less than the uninfected trees.

Trees becoming infected in middle life may have the quality of the timber reduced by the large knots formed by the basal branch burls. Burls formed in early life on the trunk cause suppression by reducing the food-transporting tissues, form open wounds for the entrance of fungi and insects and cause streaks of pitch to appear in the wood which often extends from one burl to another. Burls formed at the bases of branches produce similar injuries and may also cause a premature pruning of the branch.

Needle Cast

This disease is caused by a parasitic fungus (Hypodermella laricis) which in cases of severe infection attacks all but the youngest needles. The fruiting bodies appear as black, elongated spots on the diseased needles, which turn brown prematurely.

Primarily, this is a disease of saplings and is particularly severe in crowded stands. Infected trees are not killed but their rate of growth is reduced.

DISEASES OF WESTERN YELLOW PINE

Decay

On the whole western yellow pine is relatively sound and it is rare that the cull resulting from decay in any stand exceeds 2.5 per cent and it is usually much less. Three fungi are responsible for practically all the decay, but as yet no comparative studies have been made to determine their relative importance.

The ring scale fungus is one of these. The sporophores as a rule are larger than those developed on Douglas fir but issue through knots in the same way. Swollen knots are also developed which aid in detecting the rot. The decay first appears as a pronounced pink color in the heartwood which rapidly gives way to a red-brown, hence the names "red rot" and "red heart". During this incipient stage the wood is hard and firm. Then the white pits develop, although in some cases they appear so sparingly that they are readily overlooked. Infections commonly enter through dead branch stubs.

The quinine fungus also attacks western yellow pine. The sporophores are larger than occur on Douglas fir. A single sporophore indicates extensive decay in a tree. The typical decay with the conspicuous white mycelium felts has been described under Douglas fir. The incipient stage of the decay is quite striking. It appears as a red-brown or pronounced brown discoloration in the pale lemon to light orange-brown heartwood. The discoloration is not uniform over the entire affected portion but may occur on the radial or tangential face in broad bands of varying intensity or even intermingled with narrow bands of the normal, light colored heartwood. On cross section the infected wood presents a mottled appearance. The horizontal limits of the discoloration are bounded by a narrow band of pronounced pink or red color. At the upper limits of the incipient decay the discoloration becomes a fainter shade until it finally disappears. The discolored wood seems to be hard, firm, and strong but in reality it is seriously weakened. The incipient decay may extend for many feet in advance of the typical decay. In fact it has been known to run for 32 feet, that is 16 feet in each direction from the point of infection without typical decay developing. Infections enter through dead branch stubs and dead or broken tops.

A typical butt rot as described under Douglas fir is caused by the velvet top fungus. The rot usually runs out within 5 or 6 feet from the ground level and rarely extends higher than the first 16-foot log. Infection occurs mostly through fire scars.

Mistletoe

The Pacific slope yellow pine mistletoe (Razoumofskya campylopoda) attacks this tree very severely. Trees of all ages from seedlings to veterans are infected and often badly deformed by the parasite. The huge witches brooms on mature and overmature trees, caused by this mistletoe are too well known and conspicuous to require detailed description. Seedlings and saplings often succumb rather quickly to severe attack, but older trees may live for years, becoming badly deformed and making little or no growth.

This suppressing effect of the mistletoe on individuals and stands results in a loss far greater than is generally supposed. A comparison of a number of heavily infected trees 100 years old with an equal number of uninfected individuals of the same age showed that the infected trees were 36 per cent less in height and had made 17 per cent less diameter growth than the mistletoe-free trees.

Needle Cast

The needles of yellow pine which normally remain on the twigs from 3 to 7 years are often killed down to the last one or two years by a fungus (Lophodermium pinastri) and either drop off with the result that the foliage appears very thin or else remains hanging on the branches for many years, giving the tree a "whiskered" appearance. From green they turn to yellow and later to silvery gray. The increment of the tree is reduced by this disease. The fruiting bodies of the fungus appear as very small, black, irregular spots or short lines on the needles.

Stunted Needles and Witches Broom

A very destructive needle fungus (Hypoderma deformans) often kills all the needles except the very youngest and weakens even these. The needles are mostly short and stunted or characteristically curled. The twigs bearing the infected needles are almost always abnormally swollen or branched. The fruiting bodies appear on the needles as thin black lines one-eighth to one-half inch in length. The disease may attack only certain branches or the entire tree may be affected. Young trees are most seriously affected.

On trees mostly past the sapling stage spherical-shaped, compact witches brooms are commonly formed as the result of infection. On old trees these brooms often become very large, ranging up to 6 feet in diameter, but generally they average about 2 feet. These brooms need not be

mistaken for those caused by mistletoe, since mistletoe brooms are rather loose and quite irregular in outline.

Pine Gall Rust

Stems and branches of young trees often show a peculiar roundish swelling, usually from one-half to four or more inches in diameter and from one to five inches long. They are caused by a rust fungus (Cronartium harknessii). During the spring and early summer the bark of the swelling comes off in flakes, revealing a bright orange-yellow powdery coating, partly covered by a thin white membrane. This orange-yellow powder consists of the spores which escape when the membrane ruptures. For a time there may be an excessive development of branches and needles just beyond the gall, thus forming a small witches broom, but finally the girdling action of the fungus results in the death of the branches and needles beyond the gall. This disease is serious on seedlings and smaller saplings, frequently killing them in groups. When the leader is attacked the normal growth of the young tree is seriously interfered with.

DISEASES OF SUGAR PINE

Decay

The decays found in sugar pine are the same as those in western yellow pine and the resulting loss also is small. The quinine fungus is responsible for most of the cull that does occur. The sporophores of this fungus developed on sugar pine are unusually large. Branch stubs and dead or broken tops are the usual infection points for the quinine fungus.

Mistletoe

White pine mistletoe (Razoumofskya cyanocarpa) occasionally attacks sugar pine causing the formation of witches brooms, but on the whole the resulting injury is light in comparison with the effects of the other species of Razoumofskya on other trees described in this paper.

Blue Witches Broom

A very unusual witches broom sometimes occurs, usually on trees of pole size and upwards. The broom has the shape of a very compact, small ball, consisting of exceedingly short, brittle, bluish needles. It seldom has a diameter of more than 4 to 8 inches. The number of brooms on a single tree may vary from few to several hundred. The cause of the disease is unknown.

White Pine Blister Rust

Sugar pine is subject to attack by white pine blister rust. (See "Diseases of Western White Pine").

DISEASES OF LODGEPOLE PINE

Decay

The three wood destroying fungi most common on this host are the ring scale fungus, the quinine fungus, and the velvet top fungus. On the whole, little cull results from decay in lodgepole pine.

Mistletoe

Lodgepole pine mistletoe (Razoumofskya americana) is widespread and severe. The parasite attacks trees of all ages, deforming them and causing the formation of huge witches brooms. Badly infected trees of large size may have the entire crown composed of one or more large brooms. Naturally the increment of infected trees is much reduced.

Pine Gall Rust

This disease is caused by the same fungus as that on yellow pine, and is exactly similar in appearance except that galls on the trunks may develop much larger than they do on yellow pine. Furthermore, the fungus is much more widespread and severe in lodgepole pine stands, many seedlings being killed and trees up to pole size completely stunted and sometimes killed.

DISEASES OF WESTERN WHITE PINE

Decay

The loss through decay in this species, also known as Idaho white pine, is considerably higher than in any other pine in the west. The cull per cent varies from little or nothing in the younger age classes to 18 per cent or more in trees 200 years and older. Trees remain relatively sound until the 101-120 year age class is reached when the cull may amount to 1½ per cent. This figure will about double itself in the 121-160 year age class and from then on the increase is likely to be heavy. For an average uneven aged stand about 7 per cent is the normal loss through decay. Stands in bottoms are subject to a greater amount of rot than those on well drained slopes or benches. Normally the difference amounts to about 2 per cent. The three most important wood destroying fungi are the ring scale fungus, the velvet top fungus, and the root Fomes (Fomes annosus). Most of the cull is caused by the ring scale fungus.

Sporophores of the ring scale fungus are developed abundantly. Usually they are thin, shell or scalloped-shaped, but some are hoof-shaped. The incipient decay appears as a reddish brown discoloration of the heartwood. The typical stage is essentially the same as in other conifers. The decay not only attacks the heartwood throughout the main trunk, but sometimes occurs as a butt rot when it does not extend over 5 or 6 feet up from the ground level.

Most of the infections enter through dead branch stubs or knots although some are traceable to scars of various types. To some extent then, injuries indicate decay. Of course the best signs of decay are sporophores. Swollen knots as described for Douglas fir are also developed on western white pine and are particularly conspicuous at branch whorls often being accompanied by pronounced resin flow.

Sporophores of the velvet top fungus are not developed abundantly and those that do appear are usually to be found growing from the roots several feet away from the bases of infected trees. A sporophore occurring on the trunk appears from an old wound in the form of a bracket. The decay is confined to the butt of the tree. Infections commonly enter through fire scars.

The root Fomes has inconspicuous sporophores generally on the roots close to the surface. They are usually hidden by the forest mold. The sporophores are very irregular in outline, have a brown upper surface and a white pore surface. Incipient decay is indicated by a lilac or reddish discoloration. Typical decay is characterized by a separation of the annual rings due to the summer wood decaying more rapidly than the spring wood. In a longitudinal section small white pitted areas, something similar to the cellulose pits in ring scale rot, but with black centers are common. In the final stage of decay the wood is a whitish yellow, spongy mass. A pronounced resin flow from the butt and the roots of decayed trees is characteristic. The rot usually does not extend higher than 6 to 8 feet into the butt log.

Mistletoe

White pine mistletoe (Razoumofskya cyanocarpa) occasionally occurs on this host where it causes the formation of witches brooms.

White Pine Blister Rust

This rust fungus (Cronartium ribicola) was originally introduced from Europe into the eastern United States, where it has done enormous damage to eastern white pine (Pinus strobus) and threatened to stop all growing of this species before control measures were finally worked out.

Blister rust attacks all species of pines which bear their needles in bundles of five. On the pines the blister rust lives in the bark, although infection takes place through the needles. At first its presence is not noticeable, but slowly the bark swells and within several years from the time of infection the blisters from which the disease gets its name push through the bark early in the spring. These whitish blisters are about as large as a child's finger nail. They are usually somewhat longer one way than the other. After a few days the outer membrane which is white in color breaks open and the top falls off, exposing the bright yellow dusty spores within. These, after a number of weeks are completely blown out of the cuplike cavities in the bark. The white membrane surrounding them also disappears and there remains in the bark merely a rounded hollow which usually has a whitish, granular appearance within.

The spores from this stage can not infect other pines but are carried about by the wind and infect the leaves of currant and gooseberry plants. Here the disease appears in early summer as a yellow rust on the under side of the leaves. The spores from this stage can not infect pines, but are blown about and infect other currant and gooseberry leaves. Later in the same season the last stage of the rust appears on the diseased leaves. This consists of numerous small, brown, hair-like projections, likewise on the lower leaf surfaces. The spores from this stage can not infect currant and gooseberry leaves, but when blown to a white pine tree, they infect it, thus completing the life cycle of the fungus.

This disease kills the pines by working in the bark and girdling the tree. Its effect is not rapid, but very deadly. In general, a small tree will be killed in a shorter time than a large one, but the large tree is no more resistant to infection and ultimate death than the smallest seedling.

An idea of the damage caused by this rust fungus can be obtained from the conditions on two areas of western white pine second growth studied the past summer in British Columbia. Plot 1 covered one-third of an acre and contained 176 trees varying from 5 to 50 feet high and up to 9 inches D.B.H., with the majority ranging from 15 to 20 feet high and 1 to 5 inches D.B.H. Of these trees, all of which were heavily infected, 40 per cent were dead from the effect of blister rust. With a few exceptions they had died in the spring of 1922 and most of the infections causing death had occurred in 1915 and 1916. It was estimated that all but 4 per cent of the entire stand will be dead in 5 years from blister rust. Half of this 4 per cent consisted of 3 suppressed trees in the one-inch class which had already succumbed to competition. Of the 2 per cent remaining one tree had only a few cankers and was apparently thrifty but the other two were heavily infected and will probably die in from 6 to 10 years, leaving only one living white pine on the plot.

Plot 2 covered two-thirds of an acre and contained 425 trees ranging from saplings a few feet high up to a few trees from 13 to 20 inches D.B.H. and over 90 feet high. Eighty-two per cent of the trees were found infected, 7 per cent more were probably infected though the cankers could not be seen from the ground and the 10 per cent free from infection comprised small, suppressed saplings of no value. The infected trees were not dead yet, since the infection was not so heavy as on plot 1 due to fewer Ribes bushes. Furthermore, the trees averaged much larger than on plot 1, but all indications point to a heavy loss even among the larger trees and a complete destruction of the potential timber value of the stand within the next ten years.

So far the disease is confined practically to British Columbia and the Puget Sound region of Washington, but a sharp lookout must be kept for its appearance in the white and sugar pine regions.

CONTROL OF DISEASE

Considered broadly, forest tree diseases classify themselves into two groups. In the first group are those diseases which reduce the annual increment of the stand. Among these are diseases caused by needle or leaf inhabiting fungi and by mistletoes. In the second group fall those diseases reducing the merchantable volume. Among these are the various decays in the heartwood of living trees of merchantable size caused by different species of wood destroying fungi together with those diseases which actually kill merchantable trees outright such as chestnut blight and white pine blister rust. The last named, as a matter of fact, belongs to both groups, since they kill trees of all sizes.

Control measures for the most of the diseases native to a forest region are already known or not difficult to determine. While such diseases are serious and cause enormous losses yearly, they do not threaten to eliminate any valuable commercial species. Consequently, control measures at present, for economic reasons, are practically limited to what can be accomplished on areas from which timber is cut, but by the consistent application of sound marking principles, the condition of the second crop can be greatly improved.

The most disastrous diseases are those of epidemic character caused by some introduced parasite. Such diseases among which are included chestnut blight, white pine blister rust, and Douglas fir canker, strike at the very existence of the species attacked. In the first place, every effort must be made to prevent the introduction of such diseases by means of rigidly enforced quarantine laws. Then if an introduced disease does appear control measures must be immediately and extensively applied. Permitting an introduced parasite to become well established before attempting to control it means a losing fight, or at best, a very difficult and enormously costly one.

Mistletoe

The important species of mistletoe which must be considered are the Pacific slope yellow pine mistletoe (Razoumofskya campylopoda) on western yellow pine, the larch mistletoe (R. laricis) on western larch the Douglas fir mistletoe (R. douglasii) on Douglas fir, the hemlock mistletoe (R. tsugensis) on western hemlock, the lodgepole pine mistletoe (R. americana) on lodgepole pine, the fir false mistletoe (R. occidentalis abietina) on white fir and the incense cedar mistletoe (Phoradendron libocedri) on incense cedar.

The control of mistletoe is a problem of considerable complexity. While complete control measures are well known, their application at present is, in its entirety, not economically feasible. It would amount to the removal of all infected trees from seedlings to veterans. Until this can be done heavily infected stands can not be freed from the parasite. In the meantime we must do what we can through the medium of the most important direct silvicultural act on the National Forests, the cutting of timber.

In stands clear-cut and then burned broadcast, mistletoe is completely eliminated. Unfortunately where mistletoe infection is worst, that is in the uneven aged stands in eastern Washington and eastern and southern Oregon, a modified selection system of cutting must be practised in order to save the valuable advance growth and leave sufficient seed trees.

Since in the region mentioned yellow pine is the most valuable species and all marking practice tends to favor it, mistletoe control will naturally be concentrated on this tree but other species such as Douglas fir, western larch, white fir, incense cedar, or lodgepole pine where cut must not be neglected.

Trees with trunk infections should be removed. Such infections usually result in a malformed, short, and very limby bole of little or no value.

Individuals which though large enough are too badly distorted to be merchantable should be cut under the sanitation clause in sales agreements calling for the removal of a certain number of unmerchantable trees per acre. Such trees are a most serious danger to the surrounding stand and return absolutely nothing for the space occupied.

Since each species of mistletoe of economic importance confines itself to one particular host it is perfectly safe to leave an infected tree of one species either in company with mature trees or over reproduction of another species. This point is of most value where donkey logging is practiced because it is often a serious matter from the standpoint of injury to neighboring individuals or reproduction to remove such a tree.

In the stands in which the reproduction is free from the infection or only moderately infected every effort should be made to mark for cutting all mistletoe infected trees of merchantable size. It is in such stands that the reproduction and reserve trees can be given a chance to grow free from or with the minimum of mistletoe. The spread of the parasite from the scattered infections in the reproduction to the healthy reproduction will be show, while the upward spread to the reserve trees can be neglected entirely. On such an area in eastern Oregon in the yellow pine type eight strip acres which had previously been marked but not yet felled were cruised. The cruise showed that under the marking practiced 18 per cent of the stand by volume was reserved. To practically free the stand from mistletoe, removing all infected trees twelve inches and over diameter breast high and leaving only three infected trees between four inches and twelve inches diameter breast high would necessitate marking all but 5 per cent of the stand by volume. In case the other species were neglected but all infected yellow pines removed 10 per cent of the stand would have been left, while removing the moderately to seriously infected yellow pines, leaving ten lightly infected pines twelve inches or more diameter breast high would reserve 14 per cent of the stand.

But where the reproduction is already badly infected, where a high percentage of the trees are attacked all that can be done at present is to somewhat reduce this menace. Silvicultural reasons will of course dictate the removal of the more seriously mistletoe infected trees from the mature stand and this results in relatively heavy marking. On four strip acres in the yellow pine type in eastern Oregon where trees of all ages

were heavily infected by mistletoe it was found that 12-7/10 per cent of the stand by volume has been reserved. If all mistletoe infected trees of merchantable size had been marked for cutting, only 5 per cent of the stand would have been left. There would be little to gain by this last heavy marking since the reproduction was already heavily marked. Thrifty but infected trees can be left in such a stand with impunity, the only point that need be considered is the future effect of the mistletoe on the individual under consideration.

In these heavily infected stands it must be remembered that mistletoe is at its worst in the second growth in the seedling, sapling, and young pole stage. The badly infected trees rapidly drop out at this time leaving in the majority the uninfected individuals of those of light infection to reach maturity. The future stand should be somewhat better than the present, since the condition now existing is the cumulative result of centuries.

To sum up then, control measures at present are limited to what can be accomplished by the removal of trees above the merchantable diameter limit on sales areas. All trees with bole infections should be cut; all trees too badly distorted by mistletoe to be merchantable should be removed under the sanitation clause. In stands where the reproduction is free or relatively free from the parasite, heavier marking than normal should be practiced if necessary to eliminate infected trees. Where the reproduction is already heavily infected, marking may proceed without regard to further infection of the second growth unless mistletoe-free groups occur. These should be protected as far as possible.

The elimination of mistletoe will require a long time and owing to the fact that there exists no means for removing infected trees below the merchantable diameter limit (many of which are old, overmature trees badly suppressed by the parasite) progress for the present will be slow. But every logical effort should be made to improve the existing bad situation during the present transition period from virgin to regulated forests.

Fungus Diseases

Decays are the most important of the diseases caused by native fungi and at the same time can ultimately be brought under control with the least difficulty.

Investigations have shown that all tree species in the earlier years of their life are relatively free from decay. The age at which different species become subject to cull producing decay varies, but studies made so far on white fir, western white pine, and incense cedar show that in each case the trees attain merchantable size before this age is reached. This same principle will undoubtedly hold with other species.

Consequently in stands clear-cut and then broadcast burned future loss from decay can be practically eliminated by cutting the second stand before the age at which decay becomes of economic importance.

Furthermore, leaving a few defective seed trees scattered here and there will not menace the future stand, since even though the young trees are infected, there will be little appreciable decay provided the future stand is cut before it becomes too old. Hence, in spite of the large losses from decay in Douglas fir, the balsam firs, western hemlock, and Sitka spruce west of the summit of the Cascades, the future can be faced with the comforting assurance that such losses will be largely eliminated from the second cut.

But in stands in eastern Washington and eastern and southern Oregon the situation is more complicated. Here the modified selection system as now practiced leaves after cutting a number of trees which will be mature and overmature, in relation to decay, at the next cutting cycle. It is self-evident that such trees are liable to extensive decay. It follows then that all trees with extensive decay now standing, and particularly those with sporophores or conks, whether partially merchantable or completely unmerchantable, should be removed as a measure of protection to the future stand. Aside from a pathological measure, sound silvicultural dictates the removal of such specimens, since if not already totally worthless, decay is exceeding increment, while the suppressing effect of larger trees on the surrounding reproduction, particularly of the most valuable species, western yellow pine, is only too apparent. Unmerchantable trees can be removed under the sanitation clause. Badly decayed trees are not killed by wood-destroying fungi living in the heartwood. Such individuals are mechanically weakened, but unless mechanically overthrown they may live through several cutting cycles, just as a normal tree occupying valuable space but becoming more and more unmerchantable. Furthermore, trees with open scars should be removed, since such wounds are points of infection for wood-destroying fungi.

The same wood-destroying fungi are important in western yellow pine, sugar pine, lodgepole pine, western white pine, Douglas fir, and western larch. When these species grow in mixture, it is necessary to remove all decayed trees in order to protect any one or all of the species. On the other hand, the Indian paint fungus causing stringy brown rot so widespread and serious in white fir, does not attack any of the foregoing, while the fungus causing dry-rot of incense cedar is confined to that host. Consequently if absolutely necessary, decayed white firs and incense cedars can be left without danger to other species, but it is exceedingly poor practice to permit diseased individuals to occupy growing space to the exclusion of thrifty, young growing stock.

Since most of the native needle, leaf, and twig diseases are found primarily on young trees below the merchantable diameter limit, a great deal of control can not be accomplished under present conditions. However, from time to time, some of these diseases will be found on merchantable trees on sales areas, and such trees should be marked for cutting if warranted by the severity of the infection.

The most serious epidemic disease in the West now is the introduced white pine blister rust. This disease if allowed to go unchecked will make it impossible to perpetuate the stand of western white and sugar pine and will probably result in the loss of considerable timber before the present merchantable stands are completely logged over. Blister rust, as previously explained, requires two hosts for its existence, namely any

species of 5-needle pine (among which are included western white, sugar, and white-bark pines) and currants and gooseberries. Remove either host and the disease disappears. On this fact is based hope for control in the West.

It has been found that infection from currants or gooseberries to pines rarely occurs at a distance of more than 300 yards. By removing all currant and gooseberry bushes within a pine stand and for a distance of 300 yards on all sides, the trees can be protected from infection. While spores from diseased pines can be blown many miles and then infect currants or gooseberries, investigation has shown that the European black currant is by far the most susceptible to this long-range infection. Hence the removal of this species of currant from regions where 5-needle pines are found greatly retards the spread of the disease.

CONCLUSION

The increasing complexities of modern civilization are exposing our forests more and more to dangers and diseases undreamed of in the past. In particular, the continual increase in world commerce adds steadily to the danger of disastrous epidemics from introduced parasites. White pine blister rust is here. Douglas fir canker may follow.

It is essential that every forester should make it a part of his business, not only to keep a lookout for signs of new diseases, but also to do what he can to assist in the control of those diseases now present.